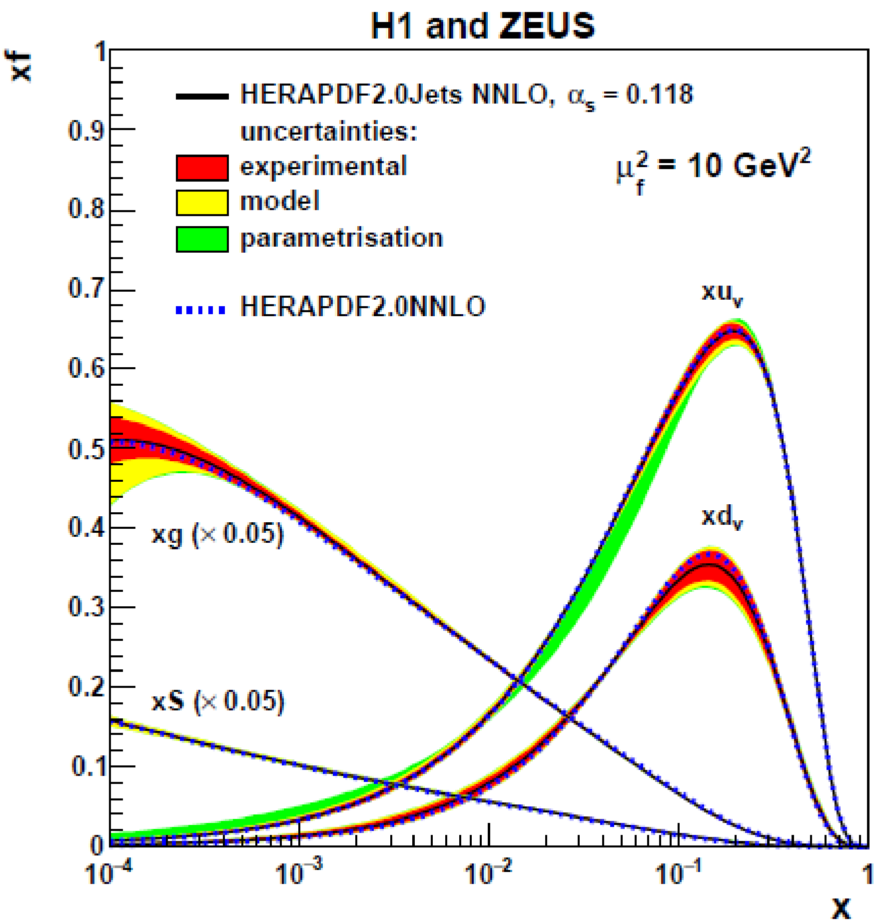
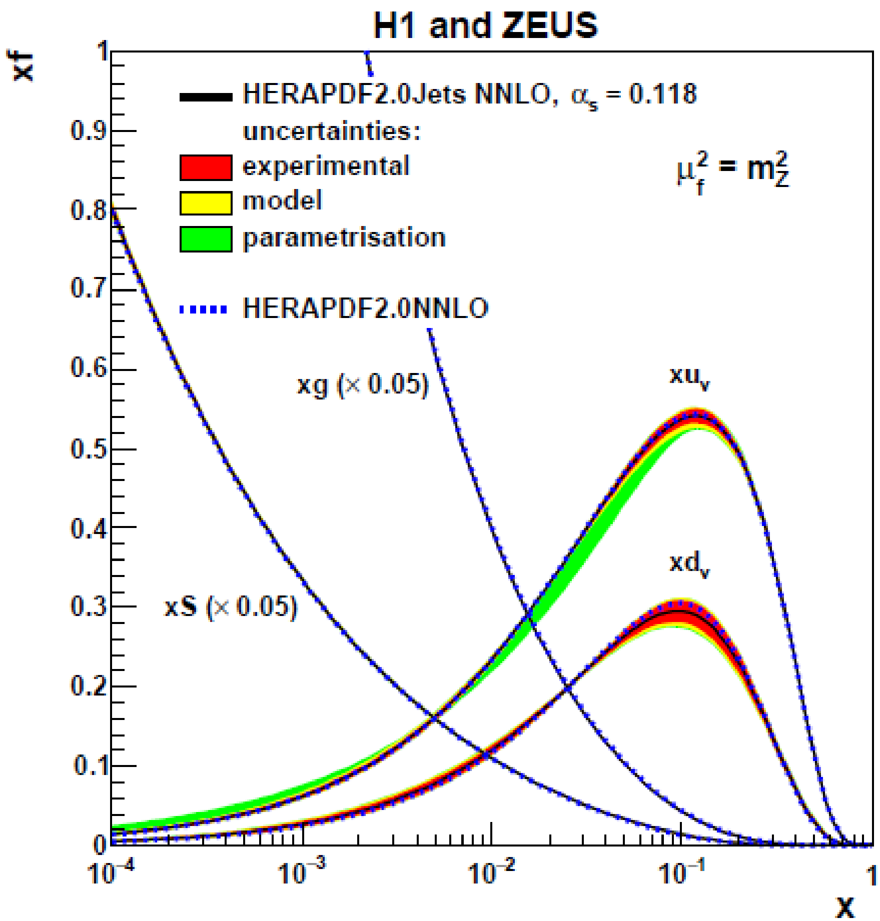
HERAPDF2.0NNLOJets
April 2020

Update to H1/ZEUS meeting of March 18th
plus follow up correspondence with the EB,
Plus follow up on the follow up from Stefan and Daniel

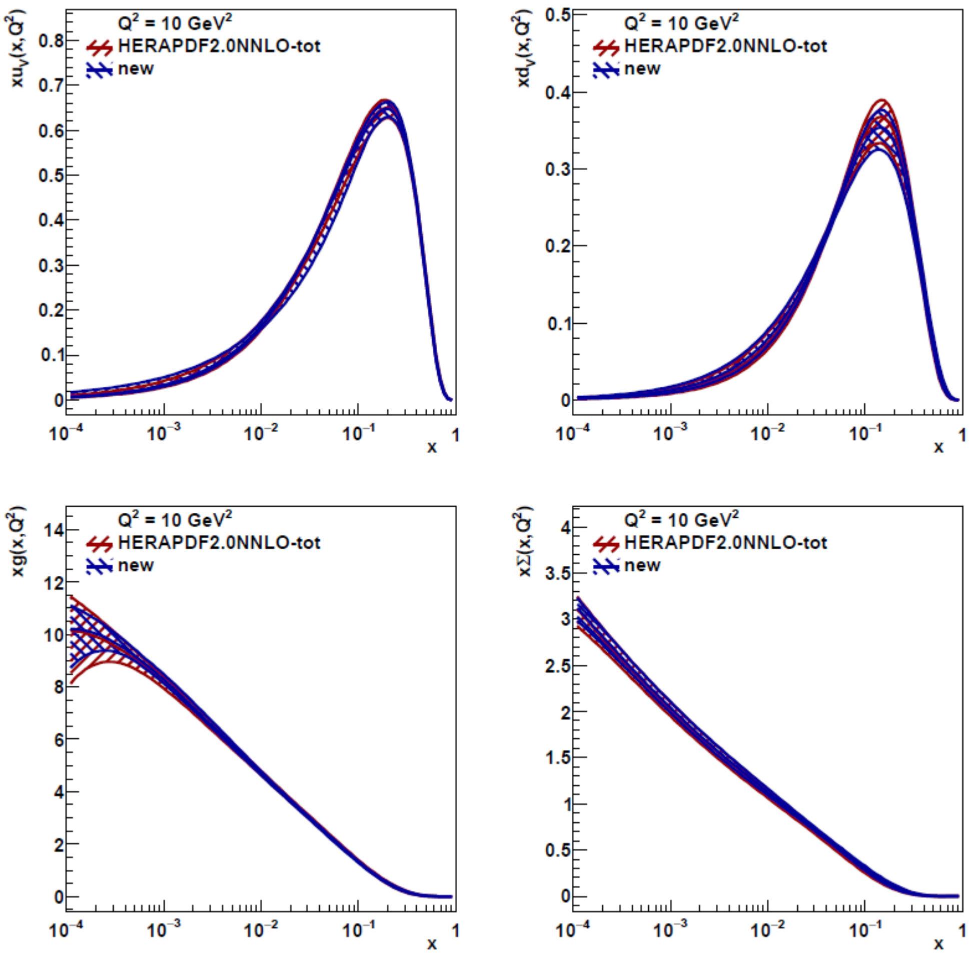
We believe we have agreement to go ahead an complete the work on a final central choice of procedures

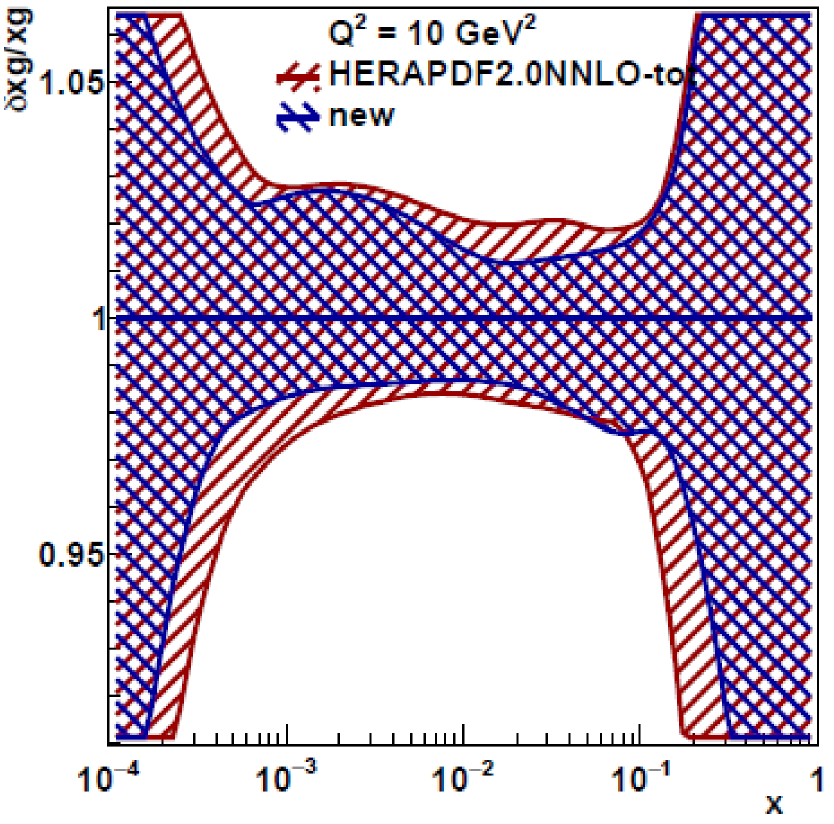
NEW alphas=0.118 NNLOJets fit - SUMMARY PLOTS
HERAPDF2.0NNLOJets compared to HERAPDF2.0NNLO





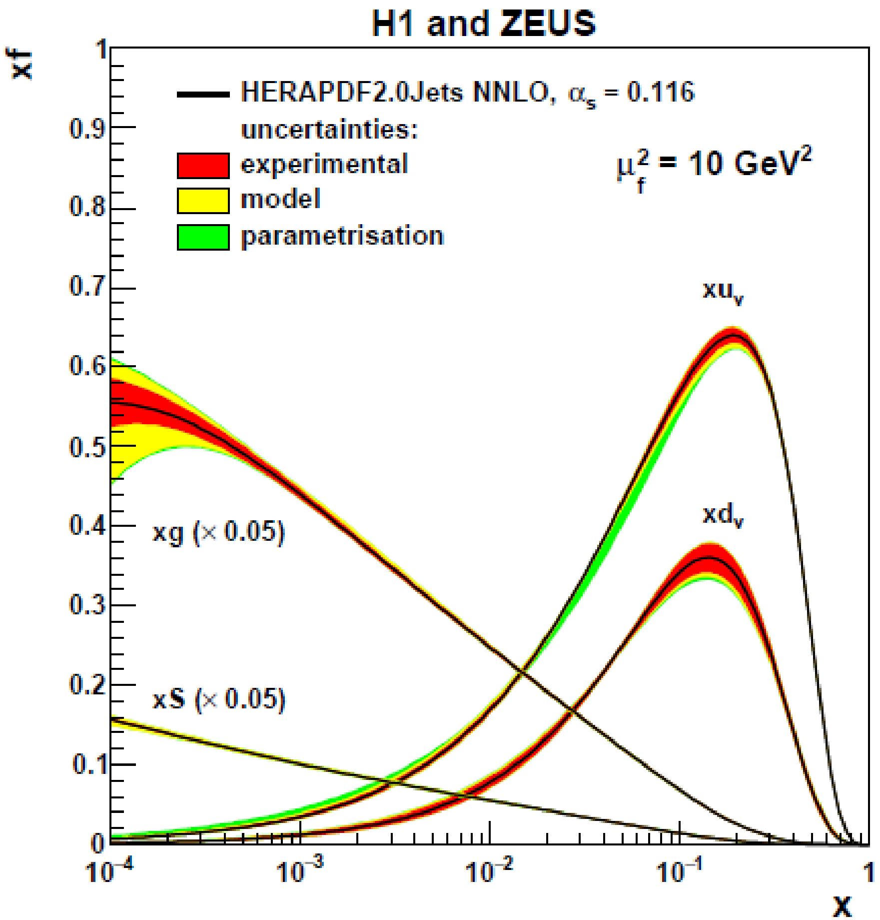
Decrease in total uncertainties from NNLO to NNLO+jet
—similar to NLO and to preliminary NNLO

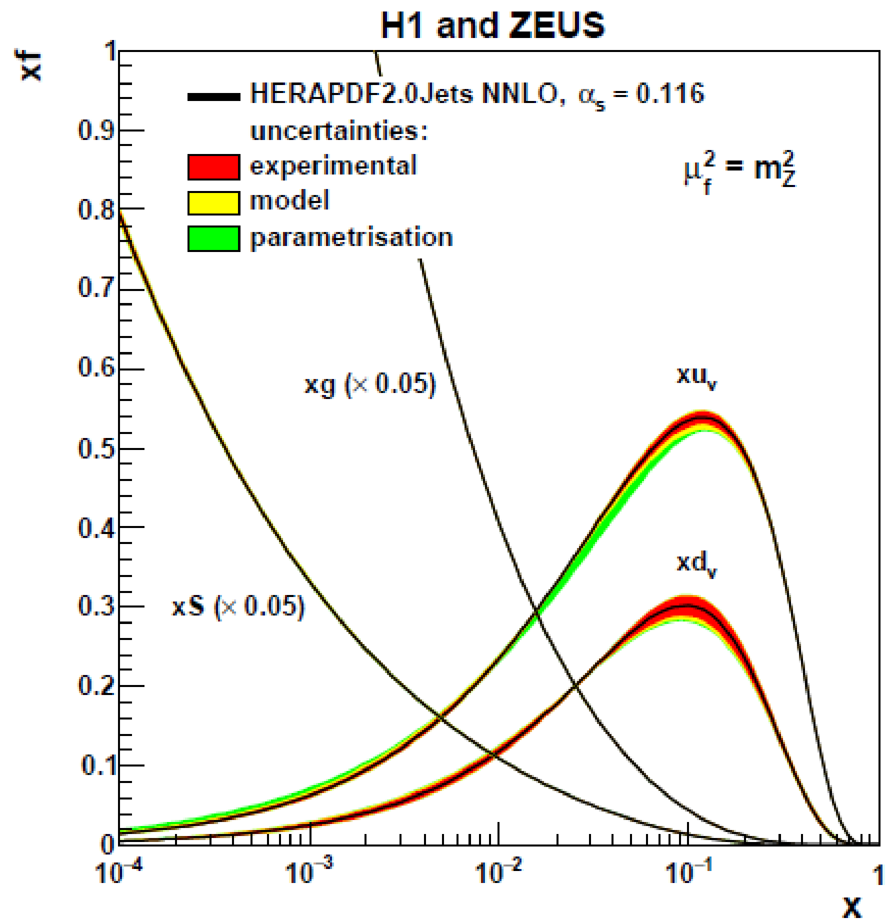




A closer look at the gluon

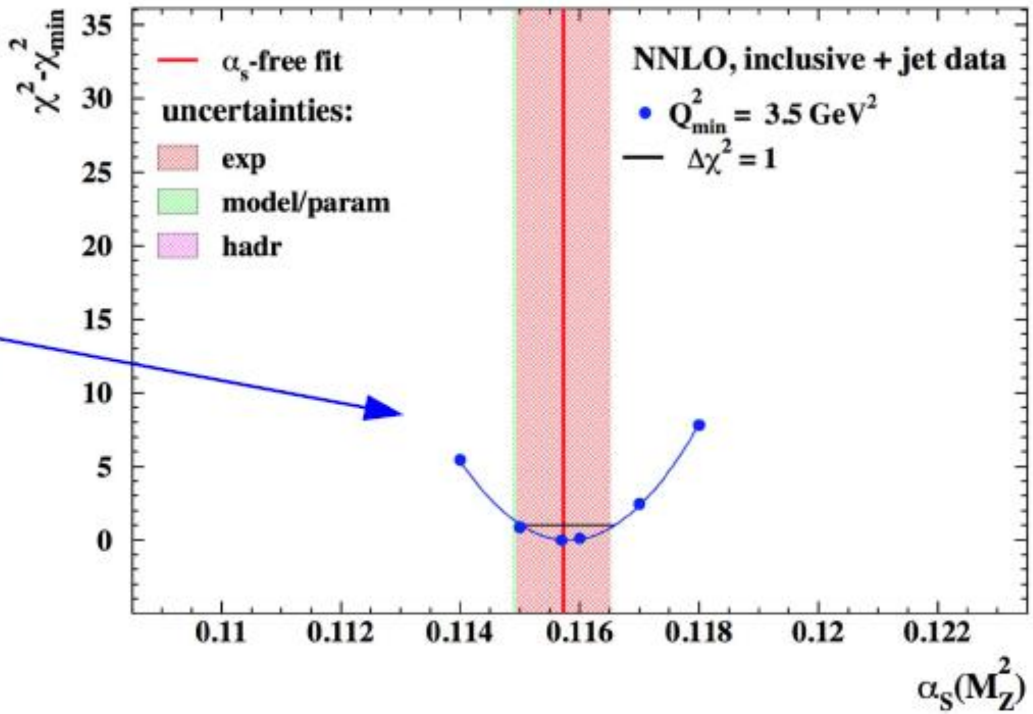
NEW alphas=0.116 NNLOJets fit SUMMARY PLOTS





New α_s

H1 and ZEUS - towards final results



- Two ways of estimating α_s @NNLO using HERA jet data
  - → α_s-scan
  - → simultaneous fit of PDFs and α_s
- Both methods give the same result

- Fit:

$$\boxed{\alpha_s(M_Z^2) = 0.1157 \pm 0.0008(\text{exp})}$$

- α_s-scan: α_s = 0.1158 +- 0.0008

- Model/parameterisation uncertainty +0.0001 -0.0003

For fits with free $\alpha_S(M_Z)$ we have now worked on hadronisation uncertainty and scale uncertainty

For preliminary, hadronisation had been treated somewhat inconsistently as a mixture of the offset method and the Hessian method. We wish to be consistent.
The treatment of hadronisation in the H1 HERA-II low Q2 jet data sets was recommended as ½ correlated and ½ uncorrelated.
At the last H1/ZEUS meeting it was decided
it would be most consistent to apply this treatment to ALL the jet data sets

So this has been applied but there are choices on the degree of correlation

1. One could correlate all the correlated hadronisation uncertainties to each other $\alpha_S(M_Z) = 0.1161 \pm 0.0010$
2. One could correlate all H1 and all ZEUS separately $\alpha_S(M_Z) = 0.1150 \pm 0.0010$
3. One could correlate only within each data set (where inclusive and dijets from the same set remain correlated) $\alpha_S(M_Z)$ 0.1157 ± 0.0009- this is closest what we were doing (inconsistently) so far

Each of these three choices give slightly different answers

Choice 1 was favoured by the H1/ZEUS meeting but it was also pointed out that the estimates of hadronization between data sets seems very inconsistent.
So we revisited this making conservative estimates

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HADRONISATION UNCERTAINTY STUDIES

We propose:

2% for all high Q2 jets--except 2.5% for the 6 new low pt points of the H1 HERA-II low Q2– and 4% for low Q2 jets.

These represent maximal values wrt the values currently used for all bins which pass the μ cut. Some investigations using 3%for low Q2 –which is a mean rather than a maximum—were also made.

CHOICE-1

One could correlate all the correlated hadronisation uncertainties to each other
And with old hadronization values we got
$\alpha_S(M_Z) = 0.1161 \pm 0.0010$

With the above hadronization uncertainty values we now get
$\alpha_S(M_Z) = 0.11584 \pm 0.00082$
This is the choice that was favoured by the meeting

We also tried 3% rather than 4% for low Q2 jets and got
$\alpha_S(M_Z) = 0.11597 \pm 0.00080$

CHOICE-2

One could correlate all H1 and all ZEUS separately

And with old hadronization values we got
$\alpha_S(M_Z) = 0.1150 \pm 0.0010$

With the above hadronization uncertainty values we now get
$\alpha_S(M_Z) = 0.11581 \pm 0.00082$

With 3% rather than 4% for low Q2 jets we get
$\alpha_S(M_Z) = 0.11599 \pm 0.00080$

CHOICE-3

One could correlate only within each data set (where inclusive and dijets from the same set remain correlated)
And with old hadronization values we got
$\alpha_S(M_Z) = 0.1157 \pm 0.0009$-

With the above hadronization uncertainty values we now get
$\alpha_S(M_Z) = 0.11568 \pm 0.00085$

With 3% rather than 4% for low Q2 jets we get
$\alpha_S(M_Z) = 0.11590 \pm 0.00083$

What can one deduce from this?

1. When more consistent choices of hadronization uncertainty values are made there is far less difference between correlation choices.
2. The exact values chosen for the hadronisation uncertainties are not crucial, 3% or 4% for the low Q2 jets makes little difference.
3. The overall uncertainty of the fit is a bit smaller when consistent choices are made- the total experimental/fit uncertainty is ~0.0008 including the hadronization uncertainty
4. The result with hadronization treated as ½ correlated and ½ uncorrelated, the correlated part treated as a Hessian error, and consistent, conservative values for hadronization uncertainty is **$\alpha_S(M_Z)$ = 0.1158 ± 0.0008(exp,had,PDF)**

There is one further satisfying result from this consistent, conservative treatment of hadronisation uncertainties. There had been some question as to **why adding the 6 extra low pt points to the High Q2 H1 data caused a shift in the central value of $\alpha_S(M_Z)$ ~1sigma (from 0.1151 to 0.1158**

When a consistent, conservative treatment of hadronisation uncertainties is used the change in $\alpha_S(M_Z)$ is not so large.

Comparing apples to apples with the 3% choice for hadronization uncertainty on low Q2

$\alpha_S(M_Z)$ = 0.11597 ± 0.0008 WITH the low pt points and

$\alpha_S(M_Z)$ = 0.11544 ± 0.0008 without them

SCALE UNCERTAINTY STUDIES

- The full scale uncertainty for all the current choices of cuts is was reported as ± 0.0036
  If this is applied as ½ correlated and ½ uncorrelated instead then it is ± 0.0026.
  But this was for the maximal variation μ_R up and down by 2
  If we take scale uncertainties as $\mu_R=\mu_F$ up and down by 2 (as in H1 paper) this is a bit smaller
  Full scale uncertainty ± 0.0034 and ½ n ½ ± 0.0025

- **The full scale uncertainty ± 0.0034 is quite comparable to those reported in the H1 study with fixed PDFs**, for comparable μ cut, since the H1/ZEUS cut is μ>13.5

H1 jets		$2m_b$	$0.1143\,(9)_{\rm exp}\,(6)_{\rm had}\,(5)_{\rm PDF}\,(5)_{{\rm PDF}\alpha_s}\,(4)_{\rm PDFset}\,(42)_{\rm scale}$
H1 jets	μ >	28 GeV	$0.1157\,(20)_{\rm exp}\,(6)_{\rm had}\,(3)_{\rm PDF}\,(2)_{{\rm PDF}\alpha_s}\,(3)_{\rm PDFset}\,(27)_{\rm scale}$
H1 jets		42 GeV	$0.1168\,(22)_{\rm exp}\,(7)_{\rm had}\,(2)_{\rm PDF}\,(2)_{{\rm PDF}\alpha_s}\,(5)_{\rm PDFset}\,(17)_{\rm scale}$

- However it is **larger than the scale uncertainty of the H1-study using a simultaneous fit of PDFs and $\alpha_S(M_Z)$**

$$\alpha_s(m_Z) = 0.1142\,(11)_{\rm exp,had,PDF}\,(2)_{\rm mod}\,(2)_{\rm par}\,(26)_{\rm scale}\,.$$

But this H1 result was done with a **Q2>10 GeV2 cut**, hence we have re-evaluated the scale uncertainty using this cut (rather than the default 3.5 GeV2 cut)
We apply this cut both on inclusive data and on the jet data whose normalisations involve low Q2.

Stefan asked for this number using our new hadronization uncertainty procedure
We obtain $\alpha_S(M_Z) = 0.1154 \pm 0.0009$ and
the resulting full scale uncertainty is ± 0.0025—so there is no significant discrepancy

So where are we?

We are sure there are no major discrepancies but we will make our own choices
we will still make the default Q2 cut and apply the usual methods so we have: full scale uncertainty ± 0.0034 and ½ n ½ ± 0.0025

Our NNLO result for the agreed procedures '

$\alpha_S(M_Z)$ = **0.1158 ± 0.0008(exp,had,PDF) ± 0.0003(mod/par) ± 0.0025(scale)**

Taking the scale uncertainty as ½ n ½ and assuming the model/param uncertainty –yet to be finalised--does not change when redone around this new central value.

People will inevitably compare it with our NLO result
$\alpha_S(M_Z)$ =**0.1183 ± 0.0009(exp,PDF) ± 0.0005(mod/par) ± 0.0012(had) ± 0.0034(scale)**

We ourselves should point out to them that the NLO evaluation was done with many differences
- The choice of scale is different
- There are no H1 HERA-II low Q2, inclusive or dijet data
- There are no H1 HERA-II high Q2 inclusive data for the lowest pt bin
- There are H1 HERA-II high Q2 trijet data
- There are more ZEUS dijet points and more H1 HERA-I low Q2 points which fail the μ cut for NNLO
- The treatment of hadronization uncertainty is different

You may not wish to go this far in the paper but for information
the most similar the analyses can be made is do both NLO and NNLO as follows:

- New scale choice
- No H1 HERA-II low Q2, inclusive or dijet data
- No H1 HERA-II high Q2 inclusive data for the lowest pt bin
- No trijets, no 6 ZEUS dijet points and μ >13.5 GeV on all data

Then at NLO we obtain: $\alpha_S(M_Z)$ = 0.1202 \pm 0.0010 and
at NNLO we obtain: $\alpha_S(M_Z)$ = 0.1141 \pm 0.0010

Thus the change from NLO to NNLO definitely does represents a **decrease in the value $\alpha_S(M_Z)$** as well as a decrease in the scale uncertainties. This is true even for a naïve comparison of published values, but is more so when done consistently, however **we have NO WISH to pursue this further.**
Daniel asked why we did not just redo the usual fit at NLO, the best reason is that the H1 lowQ2 HERA-II jets are very badly fitted at NLO and the resulting alphas value **0.124 \pm 0.001** does not seem trustworthy– This has been presented previously and agreed by H1/ZEUS

We also think that in the paper we could **point out that there are different choices that can be made as to how to evaluate scale uncertainty.**
We make the same choice as our published NLO result for maximal comparability BUT we would obtain ±0.0034 if we used a fully correlated approach.
This is then comparable to the H1 studies with similar μ cut. We may note that the H1 paper does a more thorough study of scale uncertainty, which is **beyond the scope of the current paper**.

How much we chose to say depends on the EB, these are just suggestions.

Daniel asked a further question

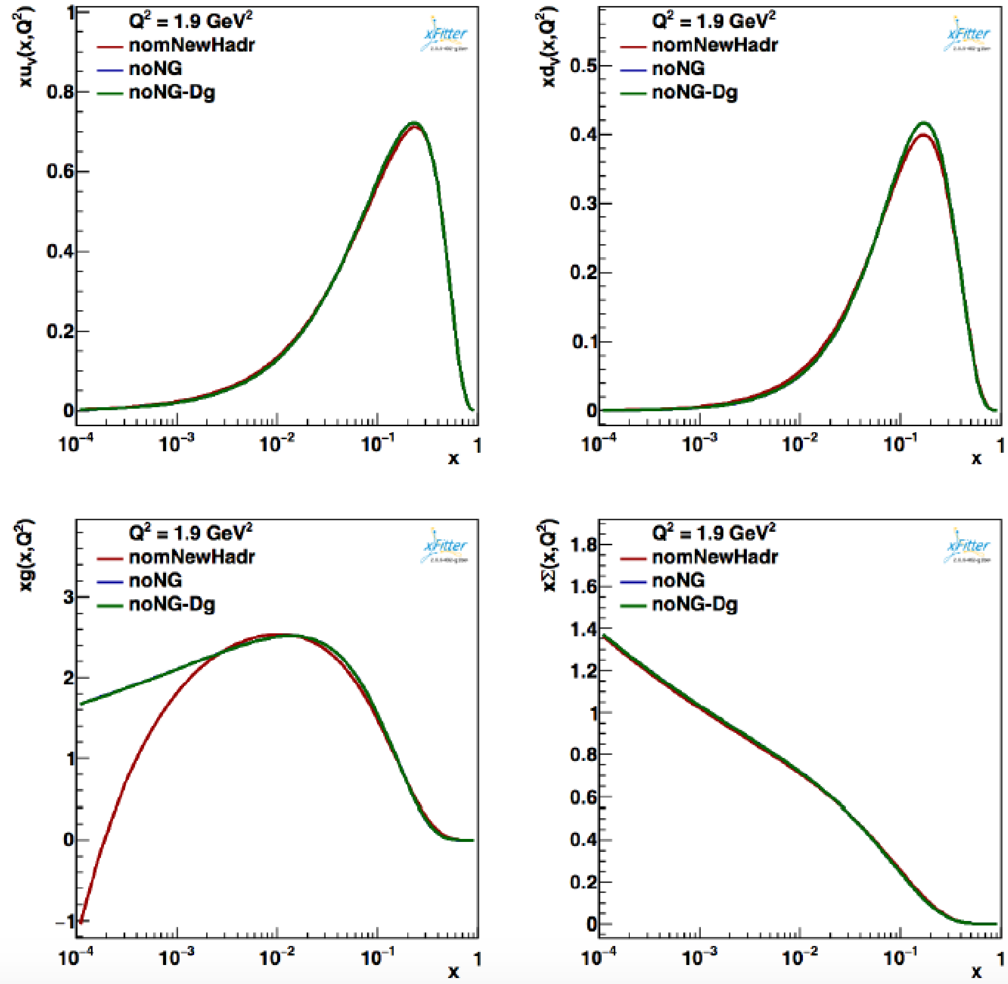
Have we considered a gluon parametrisation with no negative term?
Of course we have done this in the past but we revisit it.

- A question was asked by Daniel how does the fit - and α_s - looks like when a parameterisation without negative gluon is used
  - Two α_s-free fits tried:

    → NG term removed

    → NG term removed PLUS D_g parameter added
  - Comparison to nominal result on next pages
  - All fits done for with the new hadronisation uncertainties treatment described by Mandy - with 4% uncertainty for low-Q^2 data

- Both alternative gluon parameterisation give essentially identical results
- Gluon obviously different
- α_s consistent → see next page



Parameter	nomNewHadr	noNG	noNG-Dg
'Bg'	-0.089 ± 0.073	0.106 ± 0.023	0.106 ± 0.024
'Cg'	6.06 ± 0.52	7.60 ± 0.46	7.1 ± 1.5
'Dg'	-	-	-0.5 ± 1.3
'Aprig'	0.15 ± 0.14	-	-
'Bprig'	-0.412 ± 0.063	-	-
'Cprig'	25.00	-	-
'Buv'	0.782 ± 0.027	0.818 ± 0.025	0.817 ± 0.025
'Cuv'	4.877 ± 0.083	4.823 ± 0.086	4.823 ± 0.086
'Euv'	10.5 ± 1.4	8.7 ± 1.1	8.7 ± 1.1
'Bdv'	0.986 ± 0.082	1.062 ± 0.077	1.061 ± 0.077
'Cdv'	4.81 ± 0.38	5.13 ± 0.36	5.12 ± 0.37
'CUbar'	7.1 ± 1.6	6.6 ± 2.8	6.6 ± 2.6
'DUbar'	2.2 ± 2.4	0.7 ± 3.4	0.8 ± 3.2
'ADbar'	0.266 ± 0.011	0.275 ± 0.011	0.275 ± 0.011
'BDbar'	-0.1275 ± 0.0049	-0.1247 ± 0.0045	-0.1248 ± 0.0045
'CDbar'	9.5 ± 1.8	10.1 ± 1.8	10.1 ± 1.9
'alphas'	0.11584 ± 0.00081	0.11551 ± 0.00078	0.11552 ± 0.00078
Fit status	converged	converged	converged
Uncertainties	migrad-hesse	migrad-hesse	migrad-hesse

- Both α_s and its uncertainty consistent
- Could be included in the paper as a cross-check

As usual χ2 is larger with no negative term χ2/ndf= 1612/1537 (1612/1536) as compared to 1590/1335 with negative term

SUMMARY

We believe we have agreement on the final choices of hadronisation and scale uncertainty treatment for $\boldsymbol{\alpha_S(M_Z)}$ free fits

Everything else for $\alpha_S(M_Z)$ fixed fits was already ready.

We just need to re-run the model/parametrisation variations with the final choices and we are ready to go with the new value of $\boldsymbol{\alpha_S(M_Z)}$ free

Writing the final draft can begin